

Four trepanned skull from 5th and 16th century in Spain. Surgery or ritual?

Domènec Campillo,¹ Santiago Safont,²
Assumpció Malagosa,² Francisco-José Puchalt³

We have reviewed therapeutic cranial surgery from these epochs, evaluating the anatomical and physiological knowledge and the indications that made this therapy advisable and we have not found any reasons to include them in those criteria. We have compared them with the prehistoric trepanations practised in prehistoric populations and with those currently performed in existing primitive cultures. We followed the evolution of the «scientific trepanation» in historical populations until the apparition of Neurosurgery. We have concluded that in the cases studied no justifiable surgical indications exist and therefore our hypothesis is that trepanations were ritual acts, most likely magical or religious, which have lingered on, possibly following a traditional ancestral ritual.

KEYWORDS: Trepanation, Late Roman period, Arabian Middle Ages, Sinusitis, Paleopathology, ritual.

Introduction

Four trepaned craniums exhumed from four Spanish necropolis (two pertaining to the Late Roman period and two to the Arabian Middle Ages) have been examined and their morphology, topography and similarity of their trepanations suggest a series of reflections concerning the motives which induced such a practice.

The first trepanation, whose characteristics, we will comment on later, was exhumed in the «Torrecilla» (Arenas del Rey, Granada) necropolis which was used between the IX and XIV centuries, according to personal communication from M. Riu to Ph. du Souich (Campillo & Du Souich, 1994). The second came from the Late Roman necropolis «Can Trullàs» (IV-V centuries), and the third, pertaining to the same period, was exhumed from the «Mas Rimbau/Mas Mallol» necropolis in Tarragona. The fourth trepanation, probably dating from the XV-XVI century, is Moorish and from Benipeixcar (Gandía) (Puchalt *et al.*, 1997).

In the study of trepanations pertaining to various historical periods, we have been unable to find any justification for these supposedly thera-

¹ Museu d'Arqueologia de Catalunya, Barcelona, Spain. ² Department of Anthropology, Faculty of Biology of the Universitat Autònoma de Barcelona, Spain. ³ Department of Forensic Medicine, Faculty of Medicine, Universitat de València, Spain.

peutic interventions in the literature consulted; therefore, it appeared interesting to proceed in our study with a paleopathological slant, in an attempt to interpret the finality that gave rise to these practice.

Brief historical notice

The study of trepanation began with the discovery of trepanned craniums, which has been exhumed from the Neolithic and prior periods up until the middle of the last century (Broca, 1886-87). There has been much debate over motivations that led to this practice, quite generalised until the Metal Age, and that still persists today in some primitive cultures which currently conserve arcaics customs belonging to the pre-theoretical medicine (Lain, 1978), or certain magic or religious rituals. Our criterion is that these last ones in general had these same finalities (Campillo, 1977, 1990 and 1994). Nevertheless, the trepanations upon which we base this study are separated from anterior ones since they correspond to a historic period during which we know (due to texts) that they also trepanned.

In Greece in the fifth century B.C. medical concepts began to change significantly giving origen to Hipocrates (460-375 B.C. appx.) and his school which established medical guide lines concerning incipient technical and physiological bases (Lain, 1978). This represented the beginning of scientific medicine.

Without into detail about Hippocratic medicine, it bearns mentioning that in some of the texts he established criteria about this practice and the indications that led to therapeutic trepanation. From a technical point of view, we include the description of an instrumental ad hoc (lams. I-VIII), with technical instructions to follow as well as precautions which should be taken during the surgical act to avoid iatrogenic lesions. Likewise he presents clinical data upon which he bases his indications and contraindications of trepanation, along with the risks and complications that this therapeutic methods entailed. The principal and almost sole indications were cranial traumatismes, in particular scalp wounds associated with visible collapsed fractures (Littre, 1841).

The basic instrument for bone was the trephine, its variants being the terebra (a solid drill) and the «cylindrical trephine», denominated modiolus, similar to the «trephine crown» (lams. IV and V) which they currently use and usually trephina. According to Chacón (1850) these were the safest. They also used curettage (files), saws and pincers. The morphological variety of the perforators created characteristic orifices for each one, and each one offering distinct models, advantages and disadvantages. In general they first used a pointed trephine, similar to the current perforators (lam. VIII), with the intention of beginning the orifice. This type

of instrumental has persited until now with very few modifications, although today they are fabricated with different metals and their design has been perfected, thus increasing their safety. Generally the most simple trephine is applied by being held directly in the hand (lam. III), executing half turns in opposite directions to perforate. They also use what is called a «crossbow trephine» (lam. I and IV), although the most frequently used had a toggled handle, identical to a carpenters brace and bits (lam. V, VI and VII). With the terebra and the modiolus the orifices of trepanations were circular and easily discernible from those done in earlier periods with lytic instruments. In the middle ages they also used saws (Chacón, 1850, Vara López, 1949, García Ballester, 1967 and Borobia, 1988) (Lam. I to VIII).

Regarding localization of the trepanation, the Hippocratic school advises against trepanning in the *fossa temporalis* and over the *suturæ*, although they advised practicing in the proximity, meaning in parasutural position (Littré, 1841). As they avoided the temporal region and the pterion, we can assume that they very were familiar with the gravity involved in a *arteria meningea media* lesion, in the *fossa cranii media*, and at the level of the *sutura sagittalis*, and of the *sinus sagittalis*, of which there are no descriptions until the Renaissance.

Description of the cases

1. Cranium of the Mas Rimbau/Mallol (Tarragona). (L.P. 445)

Individual number 3227, pertaining to the Late Roman period of the IV-V centuries (radiocarbon, 1570 ± 60 B.P.¹), corresponds to an adult male, appx. 35 to 40 years old. The calvaria is conserved in deficient condition, the mandibula and the post cranial skeleton, except for the superior left extremity. The calvaria has been reconstructed through the union of numerous fragments, although without having suffered any deformation (Fig. 1), allowing the study of the lesion that interest us here. The *tabula externa* appears very eroded due to the taphonomic factors, while the *tabula interna* has hardly suffered any alterations. The cranium is gracile and almost the *suturæ* are still free, with incipient synostosis in some points of the *sutura coronalis* on its internal face.

The presence of an almost circular ellipsoidal orifice in the right parietal bone of almost anterior parasagittal localization stands out. Its diameters are: anteroposterior 9 mm and transversal 6 mm. The distal perforation

¹ According to the report by Prof. S. Mestres i Torres about the study done with a human osteological sample, coming the necropolis of «Mas Rimbau» (Tarragona). «Radiocarbon Dating Laboratory of the Chemistry Department, University os Barcelona» (1-09-199).

from its center is appx. 20 mm from the *sutura sagittalis* and 18 mm from the *coronalis*.

The form of the orifice along with the light exocranial depression and the striation in the surrounding area indicate without any doubt that the orifice was done intentionally; a trepanation most certainly done using metallic instrument, a terebra with a pyramidal point or lanceolate, creating a somewhat dull beveled exocranial border (Figs. 1 and 2). We find a small transversal posthumous fissure similar to those which we have mentioned in other cases, which are secondary to the taphonomic processes, and the trepanation having been a *locus minor resistentia* (Campillo, 1977), and with total certainty was not the motive of the trepanation. As far as know, the fact that orifice is not completely circular is due to a slight oscillation in the verticality of the terebra in the anteroposterior and posteroanterior sense, a circumstance which can still occur today when using the modern hand trephines (Campillo, 1977). In the *endocranium* the border of the orifice shows a clean-cut sharp aris penetrating a small cavity. From the external part of the cavity emerges a fairly thick sulcus from the distal branch of the *arteria meningeae media*, from which shortly before another branch detaches passing through three tunnelized sectors of a lesser diameter (Fig. 3). This cavity correspond to a fossa that accomodates, as is habitual in proximity of the *sinus sagittalis* a *foveola granulares* of Pacchioni and due to the thinness of the bone at this point, one does not see the diploe on the walls of the trepanation orifice. Although some giant *granulationes arachnoidales* of Pacchioni can perforate the bone, as some authors note (Di Salvo, 1989), we are dealing with an exceptional occurrence and usually a prior convex form visible in the exocranium is the origin. The cranium 2-3 of «Son Real» (Mallorca) can serve as an example (Campillo, 1977).

The X-ray shows a progressive thinning of the bone associated with a decrease in the diploic cells, which upon nearing the end up disappearing (Figs. 4 and 5). The image, as we have said, is typical of a *foveola granulares* of Pacchioni.

The absence of all signs of bone regeneration makes it evident that the trepanation was posthumous of it was done on a living subject, the survival span was very brief.

We consider it interesting remember that the parasagittal situation of the trepanation appears to follows lines of the Hippocratic school; «Do not trepan on the sutures, but do it in their proximity» (Littre, 1841).

What influenced the practice of this trepanation? The answer is not simple and leads us to a second question: Was it performed alive or *post-mortem*? The Hippocratic texts are the first that make mention of trepanation and they explain technique and when, where and how the perfo-

ration should be made. these norms have been followed almost without modification by the Romans, the Arabs and the remaining medieval cultures until the end of the past century.

The absence of signs of survival suggest only two opinions: 1) the individual died during the intervention or immediately postoperative, or 2) it was practised in the cadaver. According to the first option, there was a previous diagnosis that determined the intervention. The second option, allows only one possibility, that of a ritual act whose finality we will ignore.

What pathology could necessitate trepanation? The Hippocratic school and its followers only employed it in cranial traumas, almost always associated with open wounds. In the present case, it is evident that the traumatic fissure is *post-mortem*, and it can be argued that even if it had been produced while alive, it would have gone undetected to the explored and never would have been recognised as an indication for trepanation. A diagnosis of another type of pathology does not possible, and although there could have been a diminutive *sinus pericranii* or a small angioma (if any of these lesions had been large, they would have left their imprinting on the epicranium), it does not appear that with the anatomical knowledge of that period that they would have detected this indication. If indeed they really trepanned due to some concept which we fail to ascertain, the death could be the result of hemorrhage. The trepanation was centered in a point, which unfortunately with almost complete certainty would injure the second venous «cord», from which the *cortex cerebri* leads to the *sinus sagittalis* whose location correspond reasonably with this point, which is the second pre-rolandic vein of Hollinshead (1961) (Figs. 3, 4 and 5). It deals with a very daring hypothesis which we consider to be quite improbable.

2. Cranium num. 9 from «Can Trullàs» (Granollers, Vallès Oriental). (L.P. 377)

This cranium pertains to the Late Roman period (IV-V centuries) and the calotte, the maxilla and the mandibula are conserved as is almost the entire postcranial skeleton, of a mature male individual who presents a moderate erosion of the *tabula externa* and *interna* due to taphonomic causes (Fig. 6).

We do not observe any pathological alterations in the neurocranium, what does stand out is the presence of a small orifice, cylindrical, circular and appearing not to be accidental, in the left os parietale situated in a parasagittal position fairly posterior with a slightly oblique path that is a bit wider at level of the diploe. The diameter of the orifice is 5 mm and it is surrounded by a small conical area of wear that extends 5-7 mm and

has a depth of approximately 2 mm. The center of the distal perforation: 39 mm of lambda, 87 mm of bregma and 9 mm of sagittal plane (Fig. 5 and 6).

Because of the posthumous erosion of both *tabulae* it is difficult to state whether the trepanation was post-mortem or done while alive. In the case of the latter, survival times was minimal and it appears probable that the subject died during the intervention. Assuming it have been done while alive, the third or fourth «*post-central vein*» of Hollinshead (1961) could have been lesioned, or a *lacuna vasorum parasagittalis* of the *dura mater encephali*. Favouring this hypothesis is the presence of the imprinting of a vascular groove which contacts the orifice of the internal face of the *os parietale* (Figs. 6 and 7).

The X-ray (Fig. 8) does not show any signs of bony reaction and for this reason we believe that it was done post-mortem or that, having been done while alive, the subject died during the surgical act or immediately postoperative. No pathological signs were detected that would justify this intervention.

When a prior study based on current neurosurgical criteria examined this piece, they found it difficult to theorise on the conclusion of this trepanation, and discarded the diagnosis of a wound inflicted violently with a stabbing weapon, although the intentionality and use of a metallic instrument were evident (Campillo & Mestre, 1999).

Although the perforation could have been made with a pick, we believe a fine terebra was used and the situation was left posterior parasagittal thus similar to the situation in the prior case.

3. Cranium num. 156 of «La Torrecilla (Arenas del Rey, Granada) (L.P. 368)

In this Arab necropolis (XI-XIV centuries) they found a cranium with a left frontal orifice measuring approximately 4 mm in diameter, distal center some 9 mm from the sagittal plane, and that was performed with a metallic instrument that accidentally penetrated the left sinus (Fig. 9). The marks of the instrument are evident. Medina (1977) and Campillo & Du Souich (1991-1992), consider that although the infectious lesions of the pyogenic variety are frequent in paleopathology, among them sinusitis being a common affection, we are not dealing with a small cylindrical trepanation, which is lightly eroded on the external border (the same as in its *tabula externa*) and posthumous in character. At the time it was not possible to make a X-ray of the piece, but a translumination was done and no images resembling a possible sinusitis appeared.

4. Cranium of the mauresque necropolis of Benipeixcar in Gandia (XV-XVI centuries) (Puchalt et al. 1997)

This cranium (U.E. 1.603) pertains to a young adult of indetermined sex and presents a right frontal trepanation that penetrates in the sinus frontalis without any vital signs, similar to the aforementioned cases which were done post-mortem or if done while alive, the survival time was minimum. The morphology of the trepanations is circular, approximately 6 mm in diameter, distal center 15 mm from the sagittal plane and penetrating the sinus in the super-external area (Fig. 10), connecting with its superior wall (fig. 11). Given the morphology, it appears evident that drillig was performed using a metallic instrument.

The X-ray does not show any anomalies that would indicate the existence of any sinusoidal pathology (sinusitis, mucocele, etc.) (Fig. 11). This case is similar to the Torrecilla case.

The only pathology found was a *cribra oritalia*, an affection that was totally unknown until 1885 when Welcker described it for the first time and in some way would entail an indication to trepan. As in the prior cases, we lack data that would allow us to suggest a therapeutic motive.

Discussion

Although the historical medical texts describe some cases the trepanation, in truth very few trepanned craniums have found their way to the present. In analysing some of the cases, the differences in relation to the four specimens presented here are evident, as much for their situation as for their morphology. Thereby, for exemple the cranium 33 of the Visigotic necropolis of Clunia (Burgos, VI-VII century) belonging to an adult male which we studied years ago presents the following: a slightly ellipsoidal almost circular loss of bony substance in the right os parietale, the distal center appx. 75 mm of bregma and 55 mm of lambda. In the *tabula externa* the antero-posterior diameter measures 31 mm and the transversal diameter 25 mm (Campillo & Vives, 1985-1986). The perforation completely transverses the diploe until reaching the *tabula interna* which it leaves intact, the entire surface being covered by newly formed cicatrized compact tissue. According to our criteria, the lesion is an incomplete trepanation performed with modiolus, and although we ignore the motives, no fractures appear and in practice, fractures were almost the only indication during this period for trepanation, now there are no signs of any other pathology.

The cranium hailing from the Arab baths from the convent of Santa Lucía (Elx, Alacant, XV century), Botella et al. (1997) also presents a complete trepanation measuring 55x66 mm in the left *os parietale* next to the cro-

taphites, done with an abrasion technique and shows clears of survival. This type of trepanation, as well as in the Clunia case, have nothing in common with the cases that have motivated this study.

It is evident that the adequate instruments to perform a trepanation already existed before our era (Lams. I and VII), and given the morphology of the trepanations studied, it is clear that in those periods they were performed with metallic instruments.

1. The late roman trepanations

Despite the fact that the Roman followed the guide lines of the Hippocratic school, we note that the trepanations studied here were not done following the principal protocol, surely the only one that justified this therapy, and it is evident that there is no evidence of any fracture sustained while alive.

In both cases the trepanations do not affect the *sutura sagittalis*, but they are in fact in close proximity to them (Litré, 1841) (Fig. 12), preceptors advised by the Hippocratic school. In both cases the orifice is situated in the *os parietale* although one is anterior (Mas Rimbau/Mallol) and the other posterior (Can Trullàs).

We have not found any lesion that would justify a surgical action, and in our opinion the possibilti of a *sinus pericranii* (Mas Rimbau/Mallol) is hypothetical and we don't belive that in those times it would be considered a criterion to trepan. (In the case that the sinus pericranii was accidentally affected, it would have started a hemorrhage which certainly would have ceased by compression with a dressing, a circumstance which we belive would have desisted the «physical» experiency of trepanation. In summary, we do not find any scientific-clinical explanation for these trepanations.

2. The arab trepanations

The Arabs also followed the medical tradition of the Hippocratic school whose texts were translated, according to B.M. Gutiérrez-Rodilla (1998), generally from Syrian and which in tum had been translated directly from Greek. Despite the fact that their thecniques improved, in practice trepanations were only done on wounds with collapsed cranial bones. Nervertheless, the fact that in both cases the orifices penetrate the *sinus frontalis* is a coincidence that leads us to belive that they were familiar with the existence of these cavities and of sinusitis.

We have indications that before the XVI century, the presence of the *sinus frontalis* was known and therefore, the possibility of a frontal sinusitis. For

more clarification on this problem we consulted with professor J.M. López-Piñero,² who confirmed that Vesalio mentioned it in passing without giving a description or associating it with the nasal fossas in «De Humani Corpori Fabrica» (1543), Juan Valverde de Amusco (1556) being the one who meticulously described them in the «History of the Composition of the Human Body». In reference to the sinusitis, its pathological conception did not begin to evolve until the XVII century, and by the XVIII century, it was considered a pathological entity in the clinic (J.M. López-Piñero).²

Given the facts, we consider that the trepanation of individual 156 of La Torrecilla, that penetrates the sinus, to be too ancient (XI-XIV) to accept a therapeutic finality. The individual U.E. 1603 of Benipexcar, which although could have been alive in the XVI century and could be a therapeutic primitia, upon the X-ray (Fig. 11), in which no alterations suggesting sinusitis are seen, this possibility can be eliminated. What both frontal trepanations have in common is their morphology and a supra-orbital parasagittal situation.

Assessment of the trepanations

It seems clear that is not possible to allocate a therapeutic indication to the trepanations studied, and the dimensions of these orifices would hardly allow an endocranial surgical act given the means available in those times (Campillo, 1977). Its topography would not be advisable either given the high risk involved with a lesion in the sinus sagittalis, a postcentral vein or a lacuna vasorum in the regio parietalis. Similarly, no nose and throat otorhinolaryngologist specialist would to trepan in the forehead, except in an extreme situation.

The fourth trepanations have in common their parasagittal localization; in the Late Roman trepanations were localized in the os parietalis, while those belonging to the Arab culture are frontal and near the orbits. They would have pooled the advice in the Corpus hippocraticum, according to the tradition of Littré (1841), which is not supported by López-Piñero,² when marking reference to the ideal location to trepan. Although both cultural periods followed the Hippocratic tradition, given the localization of the lesions and the absence of signs of survival, the cases we are stud-

² Personal communication from Prof. José M. López-Piñero (29-3-1998): 1) «The reading matter of the surgical treatises of the Corpus hippocraticum and the 'Surgery' of Albucasi, ... of the 'Geschichte der Chirurgie' by Gurtl, seem to all point to one fact: there are no indications in the surgical sources throughout ancient times and the Middle ages concerning the location of cranial trepanations, more or less in direct relation to the sutures, thus it does not permit a clearly positive or negative answer. 2) The case of the trepanation intended to empty the pus or other pathological material from the sinus cavity is quite different. Here I think one can be fairly final because in ancient times and in the Middle ages they had not yet described the sinuses nor had they formulated anything similar to the concept of sinusitis ...».

ying appear to diverge from the canons of that school. It is interesting to note that the four individuals were adults males.

Up the past century, the indication for the trepanation were practically to open traumatisms. In the XVIII century, however, after a closed cranial traumatism when «after a space free time», a hemiplegia associated with sopor appeared in a progresive manner (typical sintomatology of the subdural and epidural hematomas), and on some occasions they decided to trepan marking this symptomatology responsible (Richter, 1802), although at the time existence of the decussation of the pyramidal paths was not clearly understood at all, nor the cerebral dominance that refers to the aphasias, until in 1861 Broca localized it topographical pathologic anatomy.

It does not seem probable that we are dealing with a punitive practice as trepanation would be too sophisticated an act and difficult to perform with a pricking instrument with no justification for stopping without lesioning the posterior wall which affects the front sinuses. In the case of the frontal trepanations, we recall that in some dating from the prehistoric times when they penetrated the sinus they would stop perforating. Their objective was to perforate the cranium and once they had perforated the sinus cavity they belived they had achieved this (Campillo, 1977 and 1994).

Even though they had begun Christianizing the peninsula during the Late Roman period and during the Arab period the islamic religion was introduced, there is no doubt that they maintained and mixed the new religions with some anterior pagan rituals.

To our understanding, prehistoric trepanations and the trepanations still done today in some primitive cultures have in general a magic-religious character; perhaps in some cases it would be a surgery of primitive concepts, differentiating some of the trepanations in wich, beginning in the Metal Age they substituted lytic instruments for metallic ones.

Lastly, we will remember that the cranium has been submitted to numerous rituals, some quite bloody (Campillo, 1977 and 1990), and sometimes sone while the subject is alive but more frequently posthumous.

Conclusions

First: In the period that correspond to the cases studied, therapeutic trepanations were done, although in practice it was almost exclusively open traumatisms. Some general guide lines existed, beginning with Hippocrates, which were followed by almost all the occidental cultures until the final part of the past century.

Second: The characteristic of the trepanations studied do nor coincide with the Hippocratic indications, nor with the medical-surgical know-

ledge of the period in which they were done, and thus they lack scientific support.

Third: Although we do not doubt that they used metallic instruments, already classic in their epochs, the fact that all the individuals trepanned were males and also that it is almost certain they were performed post-mortem, leads us to eliminate the possibility of a therapeutic finality.

Fourth: Their similarity with prehistoric trepanations, prehistoric trepanations and the ones that still continue to be performed today in primitive cultures, leads us to believe, and rather surprisingly, that we are dealing with a ritual practice probably with magical characteristics and a religious aspect that could have persisted over the centuries.

Fifth: Although there is apparently a temporal lacuna between the practice of cranial trepanations, from the end of the Bronze age and the Hippocratic trepanation, that we can consider «scientific», reintroduced by the classic cultures, we could be dealing with a historic mirage. The introduction of the rite of incineration in the Metal age impedes us from knowing if the prehistoric trepanations had continuity.

Sixth: We must confess our ignorance concerning the motivations that induced the trepanations in the cases studied; therefore, the opinions we have expressed should be considered hypothetical.

Final comments

One of our goals in carrying out this study has been to raise the problem: Which were the motives that induced the practice of the four trepanations studied? With our reflections and commentaries we are aware of the possible persistence of bloody archaic rituals. Among these we find trepanation in a period during which written medical criteria already existed establishing precise indications for cranial trepanation which have been maintained valid until the end of the XIX century.

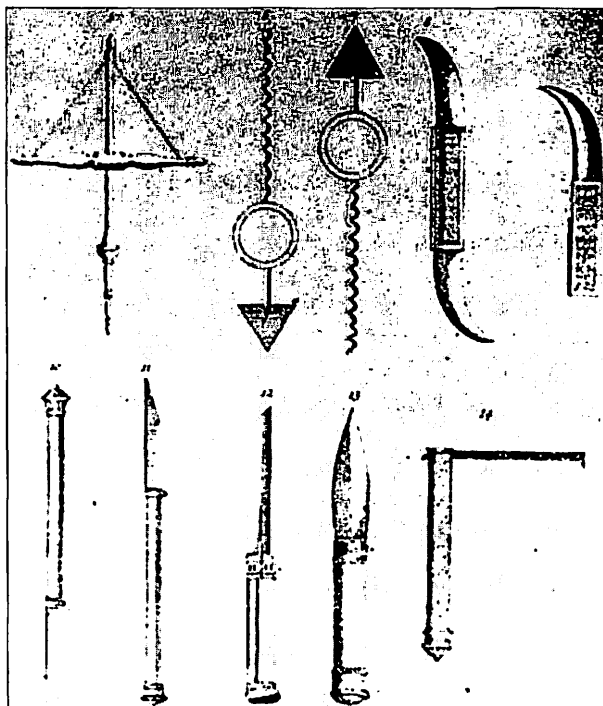
Bibliography

- BAKAY, L. (1985): *An early history of craniotomy*. Springfield, Xh. C. Thomas.
- BERENGARIO DE CARPI (1518): *Tractatus de Fractura Calve sive Cranei*. Bologna.
- BOROBIA, E. L. (1988): *Instrumental médico-quirúrgico en la Hispania romana*. Madrid, Impresos Numancia.
- BOTELLA, M., DE MIGUEL, M. P. Y ROCA DE TOGORES, C. (1997): Estudio de una trepanación procedente de los Baños Árabes del convento de Santa Lucía (Elche, Alicante). En: M.A. Macías y J.O. Picazo, (Editores): *La*

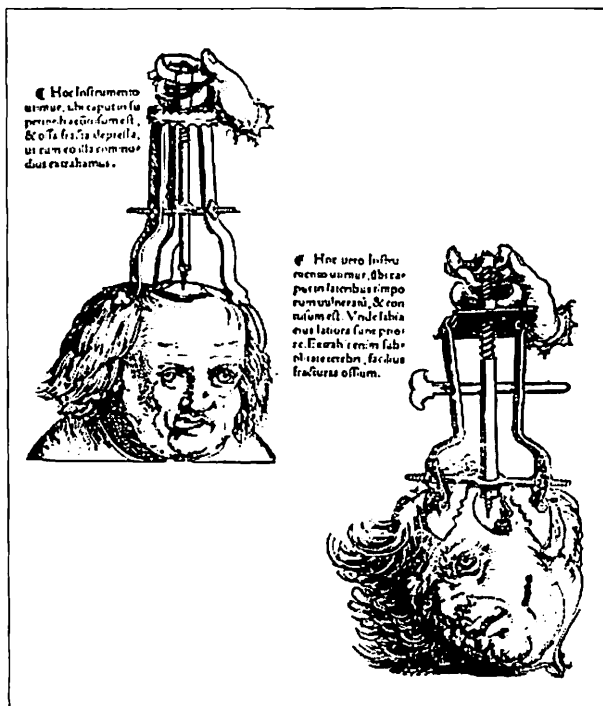
- enfermedad en los restos humanos arqueológicos*. Actas del IV Cong. Nacional de Paleopatología). San Fernando (Cádiz), 2-5/10/1997, pág. 427-428.
- BOUSIGUE, J. Y. (1985): L'opération du trépan au XVIII^e siècle. En: Actes du 110^e Congrès National des Sociétés Savantes, *Le corps humain, nature, culture, surnaturel*. Montpellier.
- BROCA, P. P. (1966-67): La trepanation chez les Incas. *Bull. Acad. de Méd.*, 32: 866-871.
- CAMPILLO, D. (1977): *Paleopatología del cráneo en Cataluña, Valencia y Baleares*. Barcelona, Montblanc-Martín.
- CAMPILLO, D. (1990): Prehistoric Trephining as a magic-religious ritual. *Proceeding of the XXXIInd International Congress on the History of Medicine*, Antwerp, 3-7 Sept., pp. 87-93.
- CAMPILLO, D. (1993-1994): *Paleopatología, los primeros vestigios de la enfermedad*. Barcelona, Fundació Uriach 1838.
- CAMPILLO, D.; MESTRE, A. M. (1998): ... (en fase de publicación).
- CAMPILLO, D.; VIVES, E. (1985-86): Exposición de nuestra experiencia paleopatológica de época medieval. *Dynamis (Granada)*, 5-6:31-58.
- CAMPILLO, D.; DU SOUICH, P. H. (1990-1991): Estudi paleopatològic de les restes exhumades a la necròpolis àrab de la Torrecilla (Arenas del Rey, Granada). *Acta Mediaevalia*, 11-12: 447-474.
- CAMPILLO, D.; MESTRE, M. A. (1998): Estudi paleopatològic de les restes humanes exhumades a la necròpolis tardo-romana de Can Trullàs. (En ...: La necròpolis romana de Can Trullas, Granollers, Vallès Oriental (segle II-III, d.C.). En curso de publicación).
- DAÇA CHACON, D. (1650): *Practica y teoria de Cirugia en romance y en latin*. Valencia, herederos de Chrysostomo Garriz.
- FUSTE, M. (1957): Restes humains exhumés dans la grotte du Toll, en Inqua V. Cong. Int. (Barcelone-Moià), Sep. 1957.
- GARANGEOT, R. (1738): *Traité des Operations de Chirurgie, Fondé sur la Mecanique des Organs de l'Homme*. Paris, Chevalier.
- GARCIA BALLESTER, L. (1967): La obra de Albucasis, culminación de la cirugía medieval. En: López Piñero, J. M. (Dir.): *La trepanación en España*. Madrid, Ed. Técnica.
- GARCIA BALLESTER, L. (1972): *Galeno*. Madrid, Guadarrama.
- GERMANÀ, F.; FORNACIARI, G. (1992): *Trepanazioni, craniotomie e traumi cranici in Italia*. Pisa, Giardini.
- GOODRICH, J. T. (1997): Neurosurgery in the Ancient and Medieval Worlds. En: Greenblatt, S.H. (Editor): *A History of Neurosurgery*. Illinois, American Association Neurological Surgeons. pp. 37-64.
- GUTIÉRREZ-RODILLA, B. M. (1998): *La ciencia empieza en la palabra*. Barcelona, Ed. Península.
- HOLLINSHEAD, W. H. (1961): *Anatomy for surgeons*, vol. I. New York, Hoeber-Harper.
- LAIN, P. (1978): *Historia de la medicina*. Barcelona, Salvat.

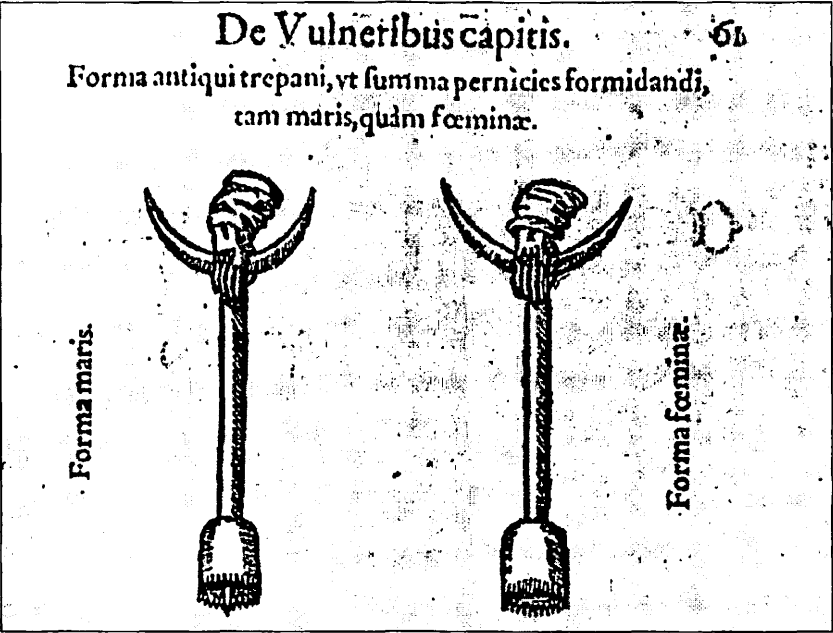
- LITTRÉ, E. (Traductor) (1841): *Ouvres complètes d'Hippocrate*. III. Paris, Bailliére. pp. 185, 221, 239-241 y 261.
- LOPEZ PIÑERO, J. M.; GLICK, TH. F.; NAVARRO, V.; PORTELA, E. (1983): *Diccionario histórico de la ciencia moderna*. Barcelona, Edicions 62.
- MAGETTI, P. (1664): *Observatorum medico-chirurgicarum sylloge*. Padua.
- MEDINA-ROSSINO, G. (1977): *Osteopatología de los cráneos de la necrópolis árabe de La Torrecilla (Arenas del Rey, Granada)*. Memoria de Licenciatura, Univ. Granada, 1977.
- MUSEU DE GRANOLLERS (1991): *Tombes y Ofrenes. Les troballes arqueològiques de Can Trullàs (Granollers)*. Programa de l'Exposició.
- O'CONNOR, D. C.; WALKER, A. E. (1951): Prologue. En Walker, A.E. (Editor): *A History of Neurological Surgery*. Baltimore, Wilkins Co.
- PUCHALT, F. J.; CASTELLÀ, M.; COLLADO, I.; POLO, M.; VILLALAIN, J. D. (1997): Trepanación sinusal en un cráneo de origen morisco. (En M. A. Macías y J. O. Picazo, (Editores): *La enfermedad en los restos humanos arqueológicos*. Actas del IV Cong. Nacional de Paleopatología). San Fernando (Cádiz), 2-5/10/ 1997. Pág. 171-174.
- RICHTER, A. A. (1802): *Tratado de heridas de la cabeza*. Madrid, Imprenta Admon. Real Arbitrio Beneficencia.
- SAFONT, S.; MALGOSA, A.; CAMPILLO, D. (1978): *Trepanation in the late Roman period from Spain*. (En prensa).
- VARA-LOPEZ, R. (1949): *La craniectomia a través de los siglos*. Universidad de Valladolid, discurso de apertura del curso 1949-1950.
- WELCKER, H. (1885): *Die Abstammung der Bevölkerung von Socotra*. Verh. 5 Deutsch Geographentag, Hamburg, April: 92-94.

Lam. I. Instruments used by Albucasis (936?-1013), according to Vesalio.

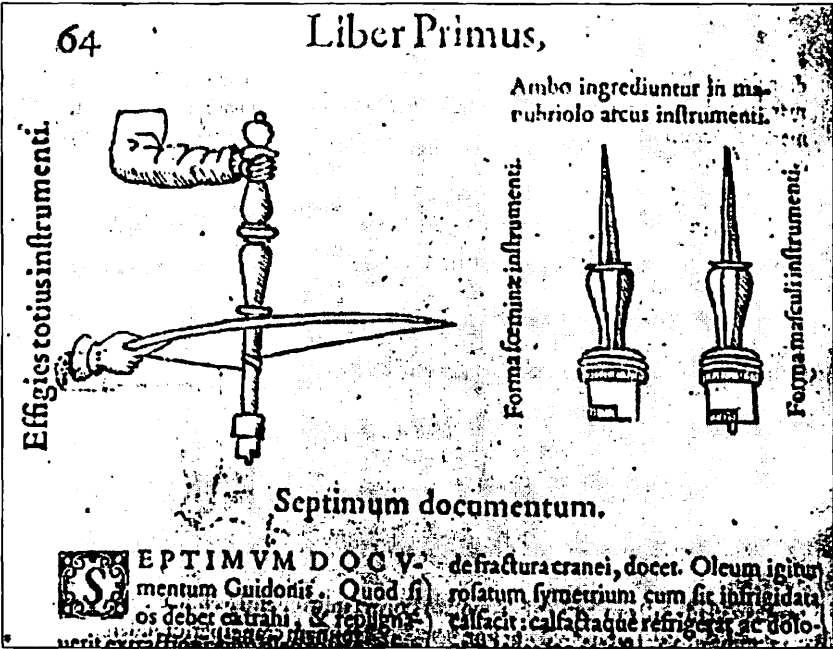


Lam. II. Support and screw perforator of Albucasis, to elevate the cranial fragments originating from collapsed traumatism.



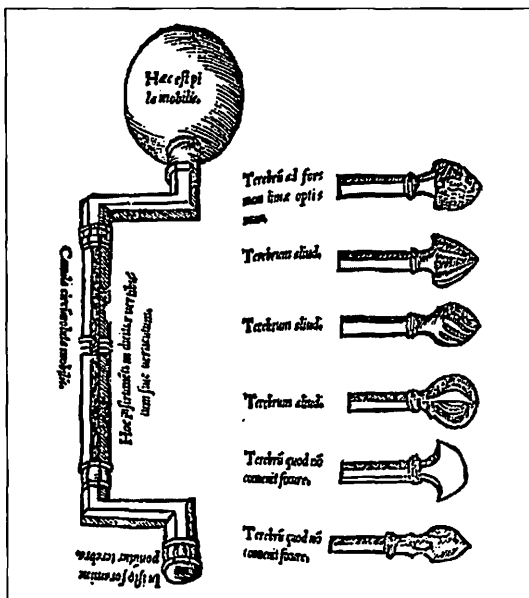


Lam. III. Hand trepan of Andrés Alcázar (1490-1585).

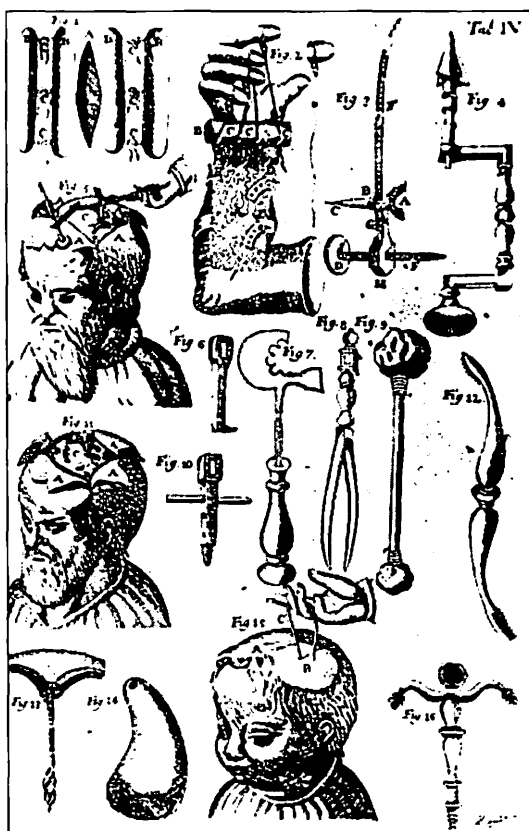


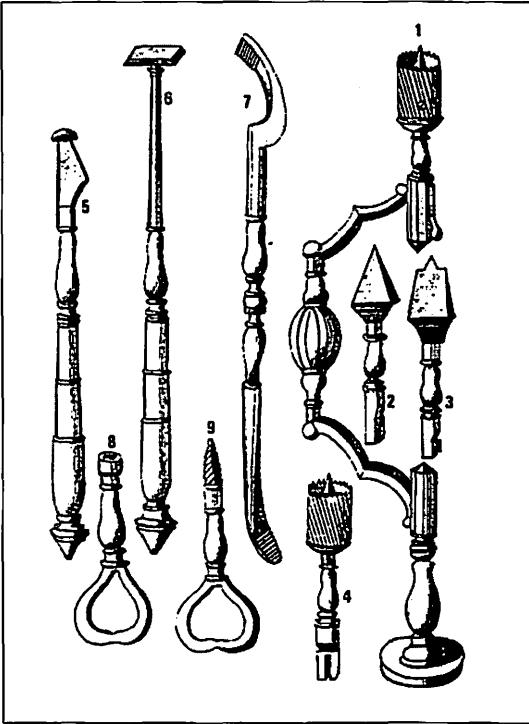
Lam. IV. Crossbow trepan armed with a drill and bits belonging to Andrés Alcázar.

Lam. V. Moviulus of Berengario de Carpi (1518).

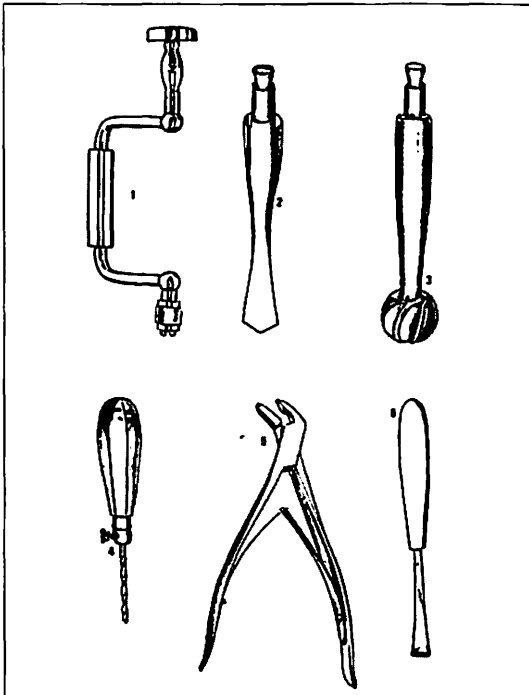


Lam. VI. Surgical instruments of Maggeti, (4) elbowed trephine (similar to the present-day trepan of Hudson^(VIII-1)) and (7) saw.





Lam. VII. Instruments for craneotomies by Garangerot (1738), which possess a notable similarity with those of present-day.



Lam. VIII. A variety of a manual neurosurgical instruments in use today: (1) toggled handle trepan of Hudson, with drill (2) a spherical drill (3), hand trephine, (5) bone forceps, (6) periosteotome.

Fig. 1. Cranial calotte of Mas Rimbau/Mallol, viewed from the exocranial face which allows of the orifice (T) in proximity to the antero-interno angle of the right parietal, mentioned in the text. One can also see various posthumous fissures, and in one of them tree small foveas (FO).

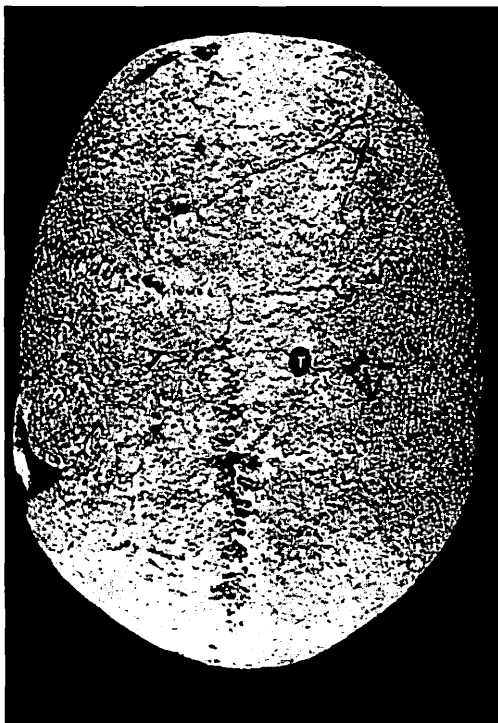


Fig. 2. Close up of the preceding figure in which we can appreciate the orifice (T), slightly ellipsoidal, with its border striated due to posthumous deterioration that eroded the exocranial face of the *tabula externa*. Three posthumous fissures, one internal (FI), and another external (FE) branch off from the orifice; the more internal of those seen in the preceding figure is that which also is seen in this enlargement (FO), above is the *sutura coronalis* (SC) which also presents a posthumous fissure (FF), which emanates from the frontal bone and penetrates the orifice (T) on the right side.

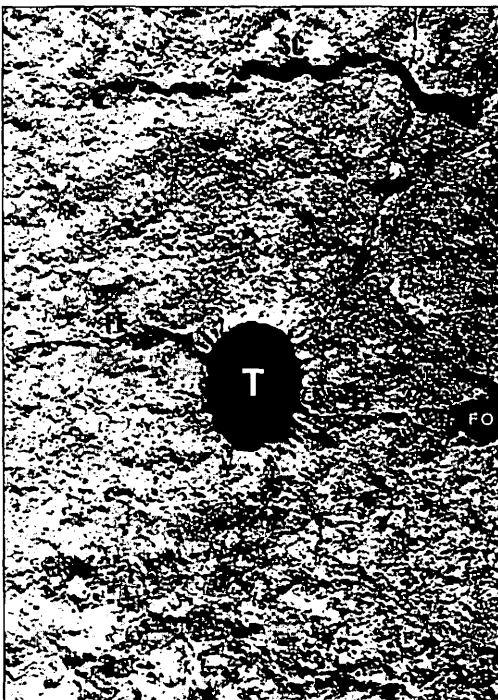




Fig. 3. Detail of the internal face of the calotte of Mas Rimbau/Mallol. (T) the trepanned orifice that penetrates in a small *foveola granulares* of Pacchioni; since no posthumous deterioration of the internal tabula exists, one can clearly see the three fissures described (FI, FE and FO), as well as another fissura superposed on the *sutura sagittalis* (FS). A branch of the *arteria meningeae media* (AMM1) penetrate in the *fossa* of Pacchioni where the trepanation is, and thus we also see another semi-tunnelized branch of the same artery (AMM2).

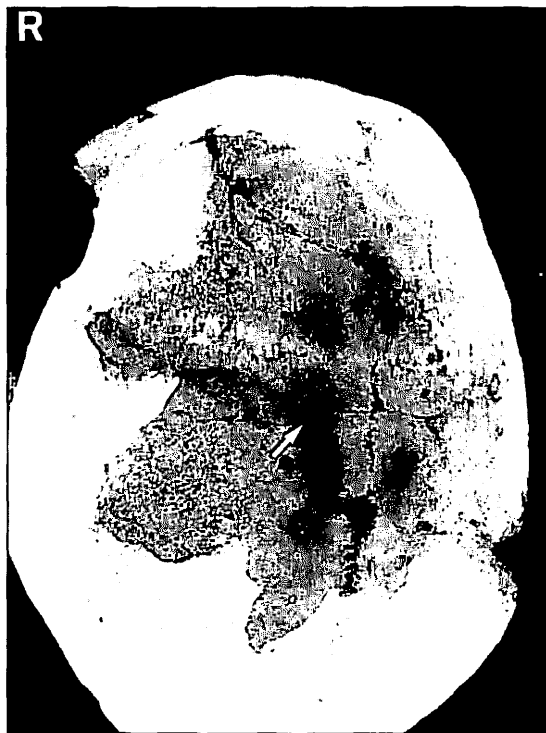


Fig. 4. X-ray submenton-vertex (Santiago Vila), somewhat oblique, the calotte of Mas Rimbau/Mallol. R, right side. One can clearly see the trepanation orifice (T) and its relation with the *suturas sagittalis* and coronalis.

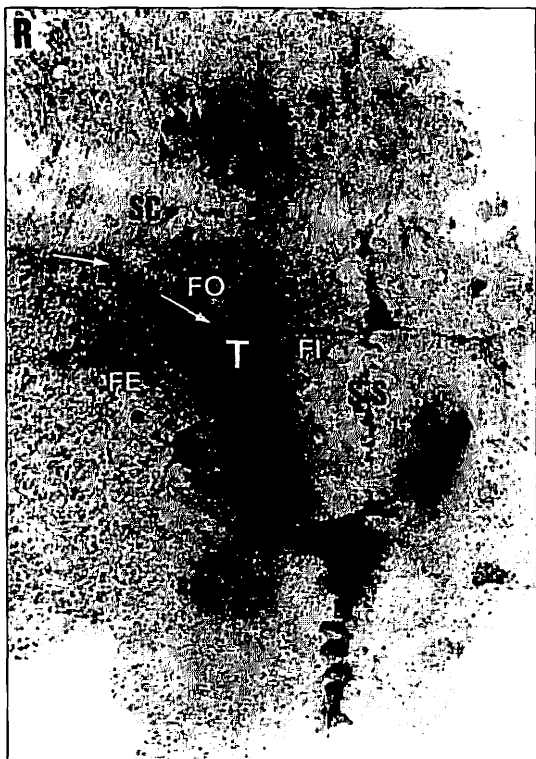


Fig. 5. Detail of the X-ray of the preceding figure: R, right side; T, trepanation; FI, internal fissure; FE, external fissure; FO, front parietal fissure; SS, sutura sagittalis; SC, sutura coronalis; the arrows indicate the sulcus of the ramus of the middle meningeal artery.

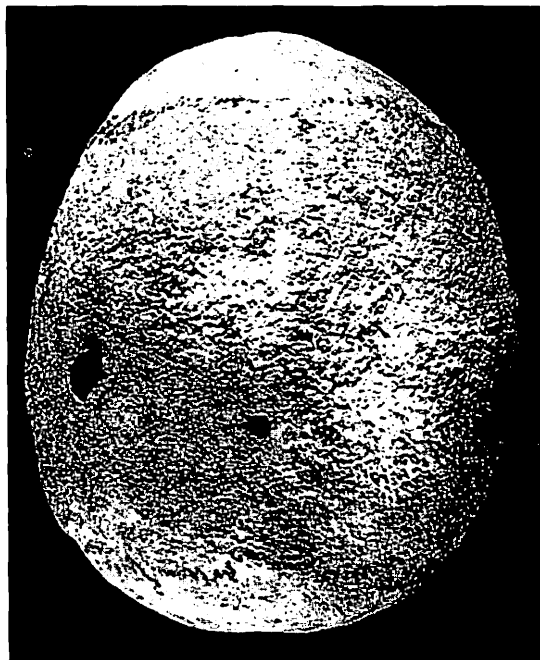


Fig. 6. Calotte of the individual number 9 of Can Trullàs, in which the small trepanation appears.

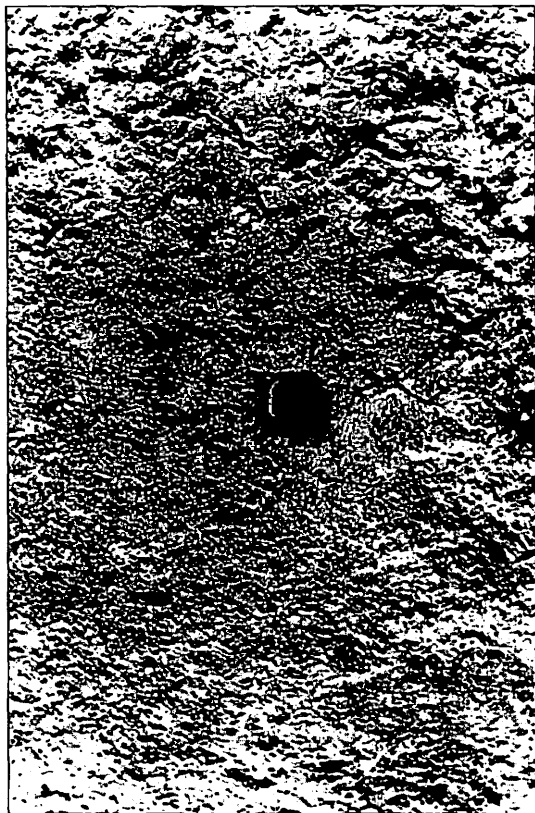


Fig. 7. Detail of the preceding figure showing that the trepanation is circular and surrounded by a slight infundibuliform depression (the border of the orifice is similar to that of the cranium of Mas Rimbau/Mallol).

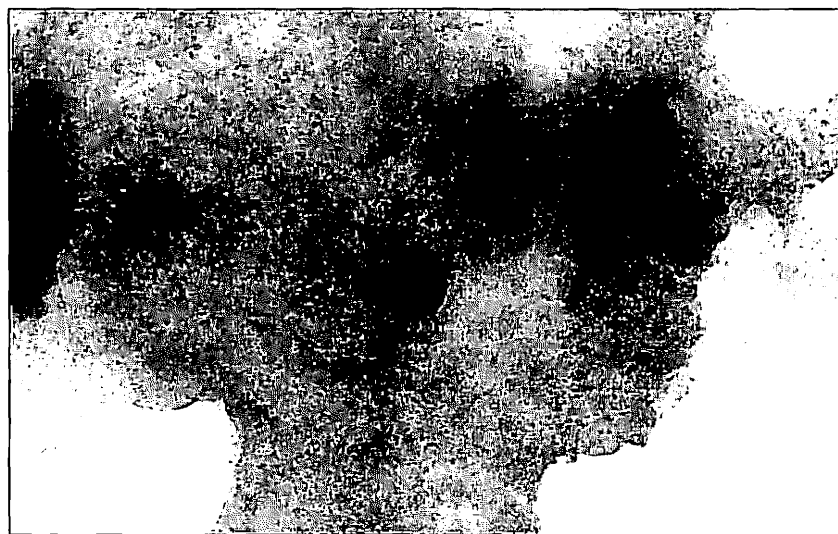


Fig. 8. X-ray of the cranium number 9 of Can Trullàs (Santiago Vila) in which one can see the absence of osteological reaction on the area surrounding the trepanation orifice.

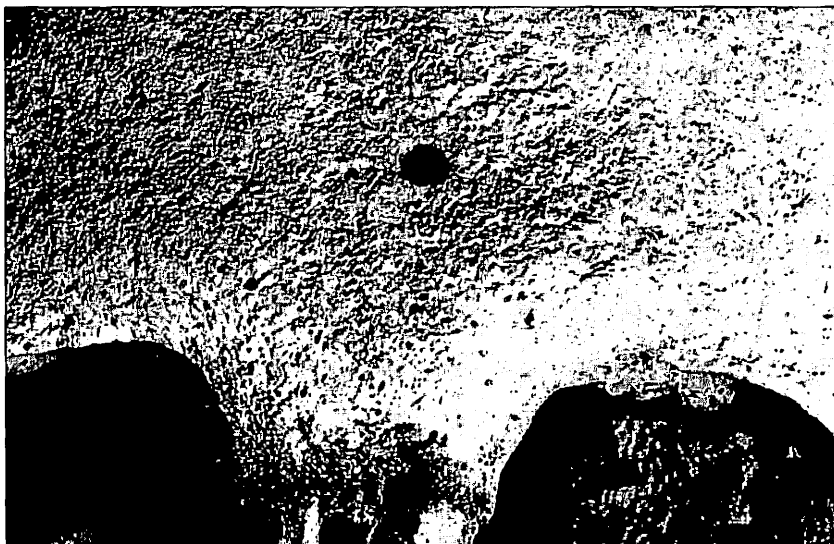


Fig. 9. Trepanation that penetrates the sinus frontalis of individual number 156 from La Torrecilla. Its characteristics are similar to those of the Mas Rimbau/Mallol, Can Trullàs and Benipeixcar.

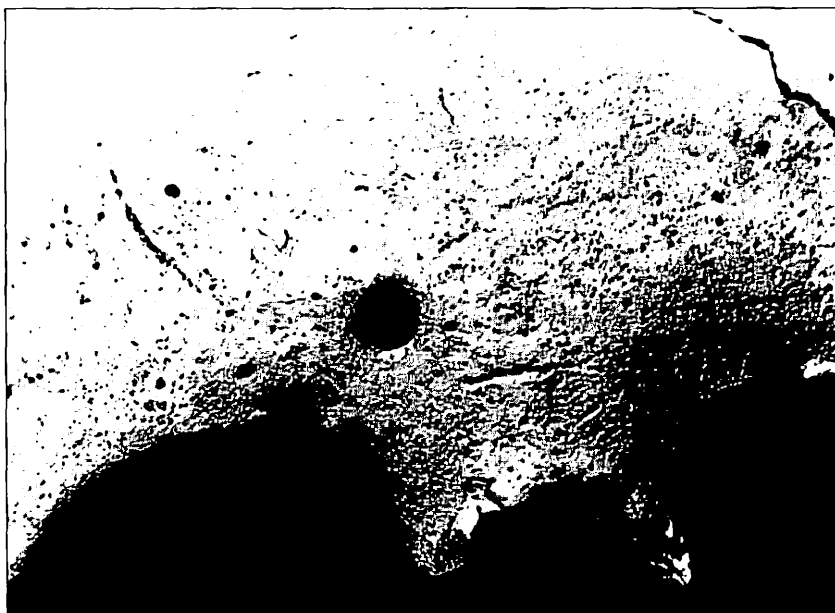


Fig. 10. Trepanation of the cranium of Benipeixcar which penetrates the right *sinus frontalis*.



Fig. 11. Radiography of the Benipeixcar cranium showing how the perforation penetrates the *sinus frontalis* next to superior limit, and no osteological reaction appears.

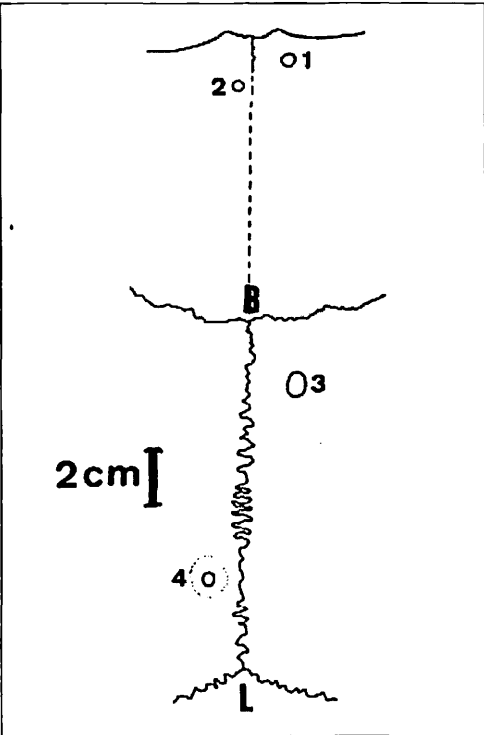


Fig. 12. Comparative schema of the situation of the four trepanations studied: 1, Benipeixcar; 2, La Torrecilla; 3, Mas Rimbau/Mallol; 4, Can Trullàs.